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Advanced Collaborative Environments Supporting Systems Integration and Design

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INTRODUCTION

Engineers at the U.S. Army Tank-Automotive Research, Development, and Engineering Center (TARDEC), in cooperation with its commercial and government partners, are combining emerging computer technologies with simulation within distributed multi-functional teams to create robust, collaborative lifecycle processes for Army materiel. As part of a continuous improvement strategy of its simulation-based development and support processes, TARDEC launched an initiative called Advanced Collaborative Environments (ACE) to better link the people and information involved in Army processes. They established new processes supported by collaboration technologies that when employed, help accelerate system acquisition.

The primary objective of this collaborative environment effort is to empower each stakeholder in a system's lifecycle with timely, relevant information in "views" that are understandable and easily accessible. ACE-enabled collaboration permits multi-functional integrated concept/product teams to simultaneously enter a virtual product design world, and jointly evaluate design issues, ideas and parameters, each from their own experience, perspective, and functional responsibility. To accomplish these objectives, TARDEC has invested in two key technologies, web-based information technology (WebIT), and immersive virtual environments (VE), that when coupled together, are catalysts for change.

These tools and organizational capabilities can be applied in any Program Management (PM) office, whether the product under development is a concept or a fielded system. These tools are independently accessible from a personal computer, or on a portable laptop, using WebIT, and/or in a common, shared virtual environment, where an entire evaluation team can come together to exchange ideas.

This paper will demonstrate the importance of collaboration within today's global business environment; will explain the advanced collaborative environment tool set TARDEC developed and assembled (WebIT and Immersive VE); will outline the benefits of their employment, and their use to support issue identification and resolution. Further, we will highlight our experiences, provide insight gained from real applications to the Army's Brigade Combat Team program, and show effects on the Army acquisition process, and identify future directions.

NEW SYSTEM DEVELOPMENT METHODS SUPPORTING VIRTUAL INTEGRATION

Traditional methods of system design and acquisition have often been described as serial and linear. They have also been characterized as a sequence of "throw it over the wall" processes where functional groups make contributions sometimes independent of other internal and external

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groups. The problem grows exponentially as a system progresses from one phase or milestone to the next. At the onset of a new milestone, one often experiences an entire change of people, information, and models used for design and analysis. As a result, critical decisions, which can significantly impact overall system design and development, are frequently made without regard to the effect on or consequences to other functional elements, and are made without the knowledge gained in previous phases.

The need to overcome some of the limitations of traditional system acquisition practices is required to meet the challenges of today's dynamic military environment. The Department of Defense has begun a strategic technology and innovation management initiative called "simulation-based acquisition"-- an integrative process designed to promote the rapid and economical development of quality products through the use of computer-based simulation. Implementation objectives of this initiative are to encourage and support iterative, cross-functional team collaboration and early user evaluations. The objectives of this simulation-supported approach are to substantially reduce product design cost, risk, and initial development time while improving the quality and utility of military transportation, weapon, and support systems.

Today, timely system acquisition success relies on the ability of cross-functional teams to share product design information, make informative decisions, and minimize system cycle time. Within this type of environment, it is necessary for individuals to share information and collaborate in the decision making process. This collaboration requires the exchange of information for purposes such as notification and clarification, and the processing of information for monitoring, negotiating, and decision making (Dhar & Olson, 1989).

Cooperation in the early phases of a system's lifecycle ensures that everyone impacted by the design has early access to product specification and relevant information, and has the ability to influence the final configuration, identifying and preventing future problems. Tools that support cross-functional team interactivity provide individual team members with accessibility to information regarding system design versions, soldier operational requirements, system models, and simulation/analytical data. These collaboration support tools also provide team members with the ability to collectively discuss system issues, formulate decisions, and respond to changes. To improve the probability of system success, these tools should allow teams to interact and make decisions from multiple perspectives in a shared information space using accurate information. The immersive virtual environments described in this paper represent one form of collaboration tool that is growing in functionality and use throughout the systems development community.

COLLABORATION TECHNOLOGIES

Many underlying technologies (e.g., modeling and simulation, network computing) form the basis of simulation-based acquisition practices. Two key technologies which compose TACOM-TARDEC's Advanced Collaborative Environments (ACE) initiative to better link the people and information involved in Army processes are: (1) web-based information technology (WebIT), and (2) immersive virtual environments (VE).

Web-based IT makes distributed information accessible in various useable forms and provides automated tools to assist in its processing. The immersive VE improves communication between process participants by providing natural shared views of system information that was previously only available to specialists. Both facilitate the vital collaboration needed in re-engineered life cycle processes.

Web based Information Technology (WebIT)

Key to improving acquisition processes is the ability to connect people and information in a timely and flexible manner. To address this requirement, TARDEC has chosen to use a Web IT framework developed by Parametric Technology Corp. (PTC), called Windchill™. It provides a web-based enterprise information management system with integrated tools to support automated workflow. Unlike existing point solutions that focus on a single department or product, such as data management or PDM, Windchill addresses product and process life cycle management across the extended enterprise.

Windchill leverages the Web's unique decentralized distribution model to "virtually" connect together many autonomous information systems, allowing them to behave as a unified whole. It utilizes existing web environments, leveraging existing investments.

Several automakers are investing in Web-IT and are investigating methods to integrate them into their processes to streamline their development efforts. For example, FastCar, a Daimler Chrysler initiative, links the flow of information from at least six of its major information systems that traditionally have not been able to seamlessly communicate. Focusing on linking finance, engineering, and purchasing, the initiative provides the organization real-time information and decision making. They recognize that designers go through hundreds of variations, and WebIT helps other groups understand what is changing in real-time. Daimler Chrysler refers to this as the "Single Point of Truth," or a unified model, so everyone can see and react. For example, a stamping engineer can watch what's happening to a design so he can make sure the company's stamping plants can actually make the body a designer creates.

One of the unique features of TARDEC's web-based environment is the desktop visualization utility. Windchill offers data visualization through its ProductViewTM component, providing full-featured viewing capabilities for parts, assemblies and drawings. ProductView lets you view data and perform other tasks without requiring access to the application that originally produced the data. Figure 1 shows a soldier accessing virtual models from his desktop. Individuals can use this tool to find data, view it, mark it up for comment and collaboration, analyze it, and take measurements. Some of the features include: (Parametric Technology, 1999)

- data access for all users in a company to any product data
- view 3-D geometric models of complex products
- view shaded, wire frame, transparent, meshed or sectioned models with accuracy
- zoom, pan, rotate, fly through, and explode components of 3-D models
- create animation sequences and enable collision detection
- measure distances including 2-point distance, point-to-axis, point-to-curve, length, diameter, and radius
- view a single geometric model of a large, complex product, even if components were created using different CAD systems
- mark up and analyze any data with dimensions, notes, and sections, and share with others for design reviews and collaboration.

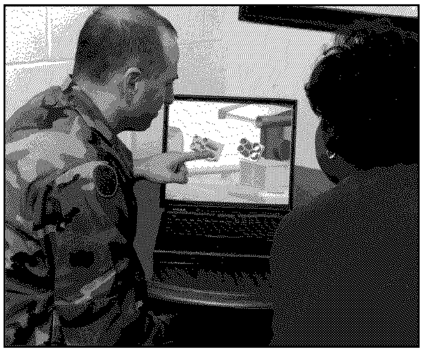

Figure 1 Accessing Product Data from the Laptop

Immersive Virtual Environments

Immersive VE technology (often-called virtual reality or VR) is a suite of 3-D graphics-based visualization software and devices, allowing multiple individuals to concurrently view a virtual system or product model while maintaining natural, human communication. These virtual systems operate within a computer-generated environment with real-time user interaction.

These technologies involve stimulating the human senses of sight, sound, and touch, making users believe they are interacting with real vehicle systems, when in actuality, they are only interacting with computer-generated replicas.

Using VE systems, a team can visualize and interact with a full system, assemblies, sub-assemblies, or components in 3-D -- a concept often called virtual prototyping (VP). Several different but related definitions for this concept exist. Some define VP as a computer-based simulation of systems and subsystems that facilitates immersion and navigation with a degree of functional realism comparable to a physical prototype (Garcia, Gocke, and Johnson, 1994). Others define VP as a mechanism for visualization and testing of computer-aided design models on a computer before they are physically created (Lee, 1995), while others simply define VP as an electronic prototype (Dai & Goebel, 1994).

From these definitions, it can be seen that VP is a simulation-based process that can be used to support the development and acquisition of new products, which is why this technology is of importance to the U.S. Army and other development organizations.

TARDEC has chosen to invest in two relatively new immersive projection technologies--the CAVE™ and PowerWall™ VE systems. These environments allow multiple individuals to concurrently view a virtual system or product model while simultaneously maintaining natural, human communication. As a result, TARDEC researchers and system developers are using this advanced high-end visualization technology to develop future military vehicle systems and to support their long-term use.

The Army has begun to establish methods and processes for the routine use of these immersive projection-based tools in future military procurements. The essence of this strategy is that all phases of system development, acquisition, and support ("womb to tomb") would be accomplished using computer simulation models and VEs.

CAVE^{TM} System Description

The CAVE™system is a multi-person, 10x10x10ft3 room-sized, high-resolution 3-D video and audio environment. The CAVE™ system uses three rear-projected screenwalls, a floor that serves as a screen, our Mylar mirrors, and four Electrochrome Marquee© projectors (Model 9500/P43). Also required are Liquid Crystal Display (LCD) stereoscopic shutter glasses (one set for each user), infrared (IR) emitters (needed for stereoscopic glass shuttering), and an Ascension Flock of Birds© electro-magnetic position sensing system (to detect X, Y, and Z coordinates and orientations of head and hand controller positions). The heart of the system is a high-end capacity Silicon Graphics Inc. Infinite Reality© computer (containing four advanced graphics processors). Also, included with this computer system are four raster manager boards, 128 Mbytes of texture memory, eight 195Mhz Model R10000 processors (used to create 1280x1024 pixel resolution stereo images on each of the four projection screens), and a hand controller (wand). Figure 2 is a picture of the layout of TARDEC's CAVE system showing the four projectors and mirror systems and their orientations. Additional devices integrated into the CAVE™ system are a 3-D sound system and force feedback haptic devices, which provide users with the sense of spatial sound and touch.

As an example, the immersive nature of CAVE technology has been used to support interior system design and ergonomic evaluations. A primary focus for organizations like John Deere, Caterpillar, NASA, the U.S. Air Force, and the U.S. Army TARDEC, has been the application of CAVE technology to support user evaluations of virtual crewstation and operator interaction in these compartments. Other useful applications include visualization and interactive interrogation of volumetric varying data as experienced in the oil industry, molecular modeling, and computational fluid dynamics.

PowerWall^{TM} System Description

Similar to the CAVE system, the PowerWall is a multi-person high-resolution 3-D video and audio environment. This large-scale visualization environment is ideal for group presentations and collaborative design reviews. The TARDEC PowerWall system (Figure 3) uses two rear-projected Electrochrome Marquee© edge-blended projectors that are used to create a high-resolution seamless image. The two-projector system can produce a 2304 x 1024 resolution image. The system is a 14x10 ft rigid flat vertical surface. Models or environments are displayed from the floor to the ceiling.

As in the CAVE, stereoscopic shutter glasses and IR emitters are used to create the 3-D stereoscopic visualization. Most PowerWall systems do not use any position and orientation tracking systems. The lack of head and hand tracking leaves more processing power for improved resolution and minimal system latency. However, in contrast to the CAVE, the PowerWall system does not provide users with a full sense of immersion.

Most applications of Powerwall technology are full 1:1 scale reviews of system or subsystem exteriors. The automotive industry uses Powerwall technology to support interactive digital styling reviews (Celsnek, 1989), virtual showroom reviews (Smith & Leigh, 2000), and aerodynamic flow simulations (Stewart & Buttolo, 1999).

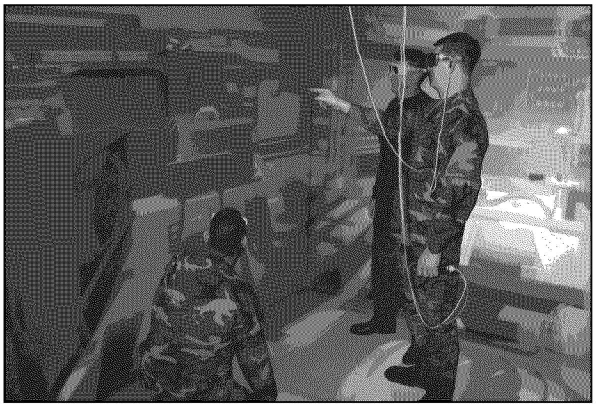

Figure 2 Soldiers Evaluating Virtual Systems in TARDEC's CAVE System

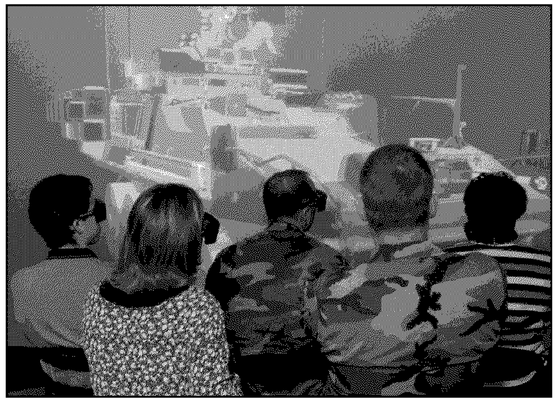

Figure 3 Exterior Full Scale Vehicle View Using TARDEC's PowerWall System

BENEFITS OF EMPLOYING COLLABORATION TECHNOLOGIES

When employed, the U. S. Army TARDEC's collaboration technologies allow cross-functional teams to assemble and solve problems while discussing requirements and design characteristics with the assistance of web-based and high-end computer hardware and software support. This capability provides a common focal point necessary, according to some researchers, for multidisciplinary (managerial, technical, marketing, and manufacturing) groups to resolve issues by sharpening their viewpoints in support of collaborative system evaluation (Barkan & Iansiti, 1993; Horton & Radcliff, 1995).

Both the web-based and immersive virtual environment systems offer the potential for true team interaction. They provide multiple individuals within a work environment to simultaneously view a virtual product or system model. All team members can either simultaneously or independently enter a virtual product design world, and evaluate system issues, ideas, parameters, and performance--each from their own experience, perspective, viewpoint, and functional responsibility. This unique multi-functional virtual system development environment allows all members to become active participants in the development effort, sharing ideas early, recognizing functional dependencies, resolving issues jointly, and making more informed decisions. The design has higher quality and utility because everyone from user to engineer provides meaningful input from the start. Everyone is involved in the process; therefore, everyone has ownership of the outcome. Ultimately you lower system development risk because fewer hidden issues will surface, directly impacting time to field and overall cost. TARDEC's experience having organizations use collaboration technologies and processes verifies these communication benefits and are described later in this paper.

Some of the benefits of employing an Advanced Collaborative Environment approach are:

- Everyone involved in the design and development starts on the same page and stays on the same page from project inception to completion.
- Consensus can be reached because participants can "see" what the vehicle (or other equipment) will look like and what it will do. Throughout the process, there is an interactive on-demand exchange of information, knowledge and experience.
- When used early in the process, changes will have the least impact on cost and schedule, and the highest impact on performance.
- The ACE facilitates working design reviews. Changes can be proposed and made while the project team is looking at the same virtual models, and before bending metal.

- Empowers the warfighters to take a direct, active role in fielding a quality system, thereby maximizing operational effectiveness.
- Expensive waiting for information and delays are virtually eliminated.

TARDEC APPLICATION EXPERIENCE

At TARDEC, earlier application of immersive VE technologies have been applied to conceptual design, product improvements of fielded systems, and most recently, to the U. S. Army's Brigade Combat Team (BCT) program. Over the past year, we have coupled these high-end visualization methods with our WebIT tools to promote even greater access of participants to system designs. The BCT program managers have used ACE-enabled collaboration to facilitate and improve communication between the Program Management Office, soldier user community, safety experts, testers and contractors. From the outset, the TARDEC ACE Group has supported the program's various integrated product teams. This section summarizes TARDEC's experiences to date.

Each of the applications involved placing soldiers, engineers, testers, and/or project managers into a common environment with a virtual representation of a vehicle system, sometimes in its operational environment. Rather than the traditional review process using briefing charts and text descriptions, these participants accessed designs from their desktop, or they were immersed inside the design alternatives and observed the functional behaviors of the systems. The improved communication facilitated by the collaboration technologies significantly reduced the time to reach a common understanding of the proposed alternatives, as well as the time to come to a consensus on many of the evaluation results.

Concept Design Reviews -- soldiers and engineers evaluating and deciding together

Some of the first applications of CAVE technology at TARDEC were its use in exploration and design review of vehicle concepts. The technology supported the Future Infantry Vehicle, Future Scout and Cavalry System, and Mobile Surgical Unit programs.

Future Infantry Vehicle (FIV) Concept Evaluations TARDEC engineers and Combat Developers from the U.S. Army's Infantry Center utilized the CAVE system to support design evaluations of the FIV vehicle concepts and to review user requirements. Prior to using the CAVE, concept development involved frequent site visits to exchange two-dimensional drawings of CAD models contained in briefing charts and text descriptions of requirements. These visits often stretched over many months. During each visit, while reviewing the questions/issues from the last visit, it was clear to the participants that neither group had a common understanding of the previously proposed concept features. Presentation of the FIV concept designs in the CAVE permitted soldiers and engineers to stand next to, inside of, and on top of the virtual vehicles and examine/discuss the various components that surrounded them (Figure 4). Many of the conclusions, which were mutually agreed to in the CAVE, would not have been found until the construction of an expensive hardware mockup.

The immersive tools supported tradeoffs between technical vehicle design and soldier operational requirements. Some of the specific issues the FIV concept review addressed with the CAVE included the following. The space claims for the squad size, which the user desired, looked acceptable on paper but after getting inside the vehicle, it was obvious to all participants that the soldiers were too cramped. Either the vehicle size constraints had to change or the squad size had to change. The location and remote operation characteristics (e.g., field of view) of a small turreted weapon at the rear of the vehicle were agreed to. The layout of stowed equipment was a common discussion topic. The selection of several technologies -- because of their effect on space claims -- was easily justified inside the virtual vehicle.

Without exception, participants thought the FIV CAVE design reviews shortened the process in determining the most promising concept solutions. These are quotes from some of the participants.

“For a year the combat developers and TARDEC engineers have been going back and forth trying to down select from five or six concept designs to a more manageable figure of three. After you guys put these designs in the CAVE, we very quickly (within weeks) had a better understanding, looking at the requirements versus the design options, allowed us to better understand tradeoffs that we would have to make.” (Infantry Liaison Officer at TARDEC).

"Now that we have the designs in the CAVE for our collaborative work with TARDEC, we must now add optional movement within short scenarios. Seeing a draft requirement function within an operational environment is much better than a large chart presentation. I want one of these at Fort Benning." (Director, Combat Development Office, Infantry Center, Fort Benning).

“By reviewing the designs in the CAVE with the engineers, discussing characteristics of the sub components allowed me to very quickly compare my requirements to the concept design capability. I am interacting with design, engineers and staff simultaneously. Things become more informal and we quickly get down to business in our tradeoff analysis.” (Combat Developer, Fort Benning).

Future Scout and Cavalry System (FSCS) The FSCS program is a joint U.S-U.K. effort with two international teams of contractors developing scout vehicle prototypes. To accelerate the effort, the program began with delivery of the Army’s in-house developed FSCS concept vehicle designs. It was important for all participants to clearly understand the concept vehicles already considered and the rationale behind them. The CAVE was used to present the initial designs to the two program offices, the contractor teams, and the two sets of user representatives. Future virtual design reviews using the CAVE of in-process contractor team designs are planned.

For this CAVE application, some functionality in terms of subsystem motion and 3-D sound was added to the geometric models. The functional simulation was used to help describe the operational characteristics of the extensive suite of sensors and a novel elevating mast that supported a sensor pod. Multiple versions of the chassis (e.g., tracked and wheeled) and multiple versions of the weapon system were presented (Figure 5). All were configured in the CAVE to be easily switched interactively so the full spectrum of alternatives was presented and dialog about trade studies supported.

Figure 4 Soldier in Virtual FIV

Figure 5 Two FSCS Vehicle Concepts and C130 Aircraft

In this application, the TARDEC concept engineers matched the support of the other participants because the CAVE reduced the level of effort needed to explain many of the new vehicle technologies, which had been rather difficult during concept development reviews. These are quotes from some of the participants.

“Letting the soldiers see the mast operate and then go up to the top of the mast and actually see what the sensor sees, makes my job of explaining the design and getting their buy-in a lot easier.” (TARDEC Concept Team Leader).

“Can the corner of the driver seat be removed so I can see the driver’s hands? How long would it take to make that change?” (Noncommissioned officer, Fort. Knox, U.S. Army).

“I can see where the gear is stowed but can I pull the duffel bags and other equipment out of the hatch using the CAVE so that I can assess this design in operation?” (Soldier, U.K. Army).
“What do we have to do to use this technology to conduct our own design reviews during development and for formal reviews?” (Project Manager from one of the FSCS Contractor Teams).

Product Improvement Reviews – program managers and engineers finding the best solutions for field issues

Some recent applications of CAVE technology at TARDEC have involved the evaluation of alternative solutions to fielded system upgrades. The technology supported the Family of Medium Tactical Vehicles (FMTV) program.

Family of Medium Tactical Vehicles (FMTV) In support of TARDEC's ongoing engineering efforts to the Program Manager (PM), FMTV, the CAVE was used to conduct the evaluation of vehicle system upgrades by PM engineers, the PM, and TARDEC design engineers. A specific case involved the assessment of several new tailgate configurations that incorporated an integral ladder. Some of the proposed alternatives that included mechanisms for automatic deployment would have been difficult to describe using only 2-D drawings.

These are quotes from some of the participants.

“It gives us the opportunity to visualize functionality of concepts when reviewing Engineering change proposals.” (Chief Engineer, PM FMTV).

"It allows the engineers to see potential interference/integration problems and how items interact together." (FMTV engineer).

"We looked at 5 or 6 solid models of tailgate alternatives in the CAVE. In one review we picked two alternatives that we are now developing detailed prototype drawings for fabrication of hardware to get to the field for evaluation. " (FMTV engineer).

"I would like to defer to my lead engineer's comments but yes, seeing the designs and their movements helped speed up the decision making process. " (PM, FMTV).

Impacting Real Army Programs – Program management office uses collaboration to support integrated product teams and system familiarization

Brigade Combat Team (BCT) The BCT Program involves the development of ten vehicle variants, with the first system being delivery 18 months after contract award. A condensed schedule and minimal or incomplete physical prototypes means soldiers would not have access or

exposure to the system until it rolled out of the factory. Therefore, the ACE strategy is key to meeting the BCT's aggressive schedule. Using collaboration tools, soldiers have become familiar with the designs and are an integral part of the design process. For the past nine months, using ACE tools, the BCT Management Office uncovered a variety of issues for each BCT vehicle configuration, including hard to detect integration issues, safety, and operator-specific issues. They have set a standard for future simulation-based acquisitions -- using ACE, they familiarized key distributed stakeholders with virtual designs, they resolved integration issues early, brainstormed potential configurations, and extended the capability to hundreds of people at their desktops.

System familiarization. In the past design reviews were conducted using traditional 2-D multimedia packages like Microsoft PowerPoint. These methods were the only means of communicating system designs to the Army warfighter. These 2-D representations provided limited understanding of the system and its functionality. Normally one had to wait until a physical prototype was delivered to have real access to the system. Today we don't rely on formal, paper-based reviews. We can use these collaboration technologies to foster real interaction with real contractor designs and have meaningful discussions. For example, vehicle integrated product teams using TARDEC's immersive CAVE system were able to see, crawl around, and begin to understand the operation of a Norway-built remote weapon station four months before the prototype was delivered or before the prime contractor completed the subsystem integration). Soldiers were able to become familiar with the design and were able to begin developing operational instructions and plans for its use.

ACE improves overall system understanding. Adding system or subsystem behaviors to the virtual models makes it clear to all how a system works, functions, and operates. We can show animated sequences of events like the tasks involved in breaking down the remote weapons station for C130 aircraft transportability, or the cycling of a round with an autoloader. Contractors participating in the session easily answer soldier questions like, "Once we remove the six bolts where do we store them?" Since models are 1:1 scale, soldiers can stand in the commander's station and check fields of view for out-of- hatch operation, scan placement of the commander's displays, or evaluate the placement of stowage items. This interactive method of communication forms consensus sooner, which differentiates between concerns users can accept within program constraints and budget.

Resolving Integration Issues. ACE technology helps identify integration problems up-front, eliminating as many problems as possible, thereby reducing risk because fewer hidden issues exist. During a recent virtual design review, the lead engineer from General Dynamics Land Systems, responsible for overall system integration of the Mobile Gun System variant, discovered an orientation problem with the manual elevation and transverse handles of the gun system, and an inaccurate wind sensor placement. These were quickly identified and resolved. Integration problems like these would have been discovered much later in the process, where fixes are more expensive.

Brainstorming Alternatives. ACE supports early brainstorming of potential alternatives. Ideas can be mocked up virtually, reviewed by the team -- allowing many design alternatives to be explored. For example, the Product Manager for the Mobile Gun System was able to brainstorm possible designs for operational doors that house the automatic rounds for the mobile gun system, a real safety concern (Figure 6). The warfighter, product manager, safety, expert and prime contractor were able to discuss possible options in the virtual environment and jointly make a decision on the best design that addresses both performance and operational needs.

Access from the Desktop. Using TARDEC's web-based system, anyone within an organization can access distributed data, search and find information, respond to tasks more quickly, and most

importantly, everyone in the process has the same valuable information at their fingertips. From the desktop, anyone can access the same design data that is used in the high-end VE simulations. Directly from e-mail, someone can easily access the same BCT variant models; they can rotate and view them from any perspective. The WebIT technologies allow participants to examine the issues, make accurate measurements, mark up the design, add comments to help facilitate solutions to problems and make individual inputs part of the entire organization's collaborative environment so that all the parties in the collaboration share the same information.

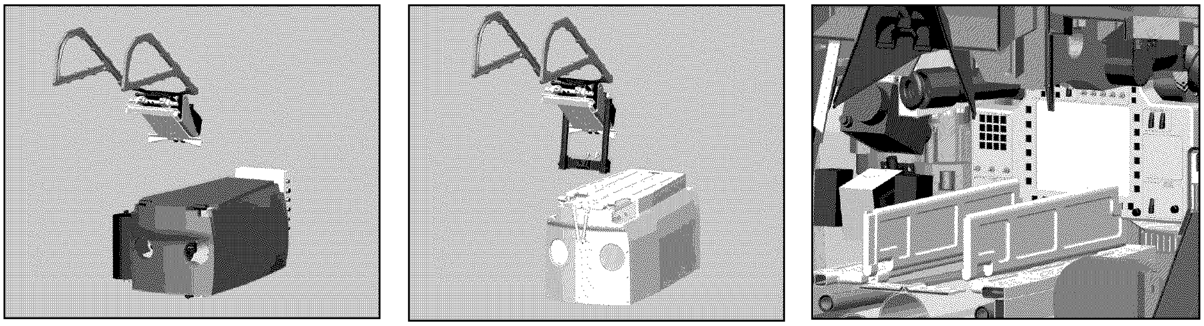

Figure 6 Brainstorming Autoloader Configurations

FUTURE VISION AND SUMMARY REMARKS

Our current global environment is confounded with complexities associated with linking distributed data, distributed information, distributed tools, and distributed human expertise. In some respects it can be considered the "Acquisition Battlefield" of today. Gaining efficiency within this type of distributed environment is the challenge. It is becoming increasingly more important for all stakeholders in ann Army system's acquisition to have visibility into the same information so that they can share a common understanding of the information and the issues, and are thus able to make more knowledgeable decisions in concert with all those involved. An acquisition strategy that focuses on collaboration promotes early and frequent involvement from all participants. Changes made to a design can be quickly assessed, and its impact to various aspects of a program to include cost, training, to logistics can be evaluated in real-time.

The U.S. Army TARDEC has chosen to establish an Advanced Collaborative Environments program and to invest in web-based information technology and new VE technology--the CAVE and PowerWall systems. Over the past two years, TARDEC established a functional immersive virtual simulation-based environment, and more recently, coupled it with information management tools to facilitate a truly integrated business environment. The ACE strategy has been applied to several real Army vehicle programs, involving real Army soldiers to resolve real Army challenges. This capability promotes the assembly of cross-functional teams to identify and resolve potential system problems early in the system development/upgrade process, where the cost of changes is reduced. Importantly, this technology allows multiple individuals to have access to early system designs and information so that all the voices of a system integration and design effort are heard. This technology supports the U.S. Army's need to significantly improve present acquisition activities and to move into a simulation-based acquisition era. However, some challenges still exist. Cultural acceptance in system processes and developing capable and trained technical people to implement these concepts still remains.

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Paper #9
Discussor's name R. McClelland
Author G. Bochenek

Q: 1) What is the cost to set up a CAVE?
2) Will it come down?

A: 1) $700,000-800,000 US plus the cost of the computer
2) Yes. In the future, PC's will replace the high cost computers and the cost of the projectors will come down.